AMENDMENTS TO THE DRAWINGS:

The attached drawing sheets include marked up and clean amended versions of Figure 9. Figure 9 is amended to insert a missing link between the center of the vertical right hand side of tilt control 156_1 and the center of the vertical left hand side of splitter 154_3. This amendment to Figure 9 finds support in at least Figure 3 which shows the same link between tilt control 46 and splitter 52.

Attachments: A Marked-up version of Figure 9 is included at Appendix B.

A "Replacement Sheet" for amended Figure 9 is included at Appendix C.

REMARKS

Claims 1-9, 11-23 and 26-33 are pending in the application.

Independent claims 1 and 16 are amended above to more clearly set forth what the applicant regards as the invention. No new matter is added to the specification or claims by these amendments.

I. THE SECTION 112, 1st PARAGRAPH REJECTION OF CLAIMS 12 AND 27

Claims 12 and 27 are rejected under 35 U.S.C. 112, first paragraph, as allegedly failing to comply with the enablement requirement, i.e. that they contains subject matter not appropriately described in the specification. The Examiner states "It is contradicting *(sic)* to claim the second splitter incorporates first and second splitter *(sic)* while claiming they are remotely located."

This 35 U.S.C. 112 rejection is traversed because there is no contradiction in claim 12 or 27. The Examiner's rejection ignores Applicant's Figure 12 and related description at page 34 lines 9-21, and confuses splitting apparatus with splitters. Taking the contradiction issue first, a splitting apparatus may be a single splitter but it may also consist of more than one splitter. This is only the equivalent of cycling apparatus having one or more cycling devices – i.e. wheels – e.g. a unicycle, bicycle, tricycle or quadricycle. In Figure 4, the "second splitting apparatus" consists of two splitters 52 and 54 which correspond to the "first and second splitters" of claims 12 and 27. Figure 3 shows a first splitting apparatus which is a single splitter 44, as does Figure 12 in Applicant's patent specification – i.e. tilt control section 212.

The tilt control section 212 uses a splitter (no reference numeral) to divide an input signal Vin into two signals V1A and V1B; V1A undergoes a fixed phase shift Phi.fix and V1B undergoes a variable phase shift indicated by T with superimposed diagonal arrow. This produces two signals V2A and V2B with variable phase shift relative to one another. The tilt control section 212 is not described in detail in related description at page 34 lines 9-21 because equivalent tilt control has already been described in detail on page 16 lines 14 – 24 and page 17 lines 19-26 with reference to Figure 3 (see items 42 to 48).

Referring to Figure 12, Applicant's specification at page 34 lines 12 – 16 states: "The tilt control section 212 may now be located with a user remotely from the antenna array 60 and mast on which it is mounted, and an antenna feed network 218 (see e.g. Figure 4) may be co-located

with the antenna array 216." Now the tilt control section 212 is a combination of a splitter or 'first splitting apparatus', a variable phase shifter and an optional fixed phase shifter: page 34 lines 12 – 16 is therefore saying that the splitter or 'first splitting apparatus' and a variable phase shifter may be located remotely from the antenna array. Moreover, the antenna feed network 218 in Figure 12, which corresponds to network 70 in Figure 4, may be co-located with the antenna array 216 (or 62 in Figure 4) as stated at page 34 lines 12 – 16 again: Figure 12 shows two signals V2A and V2B with variable relative phase shift passing from tilt control section 212 to two feeders or feeder cables 214A and 214B and then to an antenna feed network 218 as per e.g. network 70 in Figure 4: network 70 has two splitters 54 and 52 which respectively divide each of signals V2A and V2B into five component signals for vector combining in hybrids 60_1 to 60_4. Splitters 54 and 52 are therefore "first and second splitters" which collectively form a "second splitting apparatus" and hybrids 60_1 to 60_4 together with their input and output connections collectively form a "signal combining network", and splitters 54 and 52 and hybrids 60_1 to 60_4 may be co-located with the antenna array as stated on page 34 lines 12 – 16, and as shown in Figures 4 and 12.

Consequently, all the elements of claims 12 and 27 are fully disclosed in Applicant's specification, at page 16 lines 14 – 24 and page 17 lines 19-26 with reference to Figure 3, page 20 lines 8 -16 with reference to Figure 4 and page 34 lines 12 – 16 with reference to Figure 12: these elements are a first splitting apparatus 44 and a variable phase shifter 46 located remotely from the antenna array, together with a second splitting apparatus comprising first and second splitters 52 and 54 and a signal combining network co-located with the antenna array, as shown in Figure 12 in both cases. The 35 U.S.C. 112, 1st paragraph rejection is therefore without merit and should be withdrawn.

II. TRAVERSE OF THE OBVIOUSNESS REJECTIONS

A. Claims 1, 5, 11, 13, 16, 20, 26 And 28 Are Non-Obvious

The Examiner rejected claims 1, 5, 11, 13, 16, 20, 26 & 28 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shapira (2006/0068848) in view of Thomas (2004/0209572), newly cited, hereinafter 'Thomas 72' to distinguish from Thomas (2004/0252055), hereinafter 'Thomas 55'. It is the Examiner's position that Shapira discloses all of the features of claims 1

and 16 except for the vectorial combiner element. The Examiner relies upon Thomas for providing the missing teaching. However, all of the rejected claims are non-obvious and patentable because the Examiner has not made out a prima facie case of obviousness. In particular, Shapira at least does not disclose claim 1 and 16 features (b) and (c) as the Examiner maintains.

Shapira Figure 3 and paragraphs [0056] and [0057] disclose two phased arrays, each phased array consisting of the minimum number of antenna elements required for a phased array, i.e. two antenna elements. There are two leftward pointing elements 22 in one array and two rightward pointing elements 24 in the other array. A common transmit signal at 36 provides input for both arrays: the transmit signal is split into two at 38, and the two signals are split again to provide two antenna element signals for each array. One of the two antenna element signals for each array passes via a respective variable phase shifter before reaching an antenna element but the other does not, i.e. variable phase shifter 26 for one of the elements 22 in the leftward pointing array and variable phase shifter 28 for one of the elements 24 in the rightward pointing array. This makes it clear that Shapira's equivalent of "relatively phase shifted first and second signals" are signals reaching a pair of antenna elements 22 in one array or a pair of antenna elements 24 in the other array, one signal of each pair having passed through a variable phase shifter 26 or 28 but the other not having done so.

Consequently, the Examiner position that Shapira discloses relatively phase shifting signals being subsequently divided into component signals is wrong. Shapira's equivalent of "relatively phase shifted first and second signals" pass directly to antenna elements 22 or 24 without any splitting or vector combining whatsoever. The Shapira disclosure in Figure 3 and paragraphs [0056] and [0057] requires direct connections between phase shifters 26 and 28 and antenna elements 22 and 24 respectively with no intervening splitting apparatus for splitting signals into component signals. Indeed all that the Examiner has stated that Shapira discloses is a "splitter article 38". The Examiner has not shown, because he cannot, that the Shapira discloses a splitter that either (1) accepts a relatively phase shifted first and second signals; and (2) that divides the relatively phase shifted first and second signals into respective component signals. For as least this reason, the Examiner has not made out a prima facie case of

obviousness of independent claims 1 and 16 so the rejection of claims 1, 5, 11, 13, 16, 20, 26 & 28 must be withdrawn.

The Examiner's rejection of claims 1, 5, 11, 13, 16, 20, 26 & 28 must also be withdrawn because he has not shown that the cited prior art discloses feature (c) of claims 1 and 16. That is because Shapira discloses neither component signals divided from relatively phase shifted first and second signals or a signal combining network for forming vectorial combinations of such component signals. Instead, as discussed above, Shapira discloses feeding relatively phase shifted first and second signals directly from phase shifters 26 and 28 to pairs of antenna elements 22 and 24 without any intervening signal processing whatsoever.

The Examiner's reference to a phase difference being a vector difference is (1) wrong, and (2) irrelevant. A phase difference such as π is a scalar quantity because it has one component, magnitude; vectors (whether differences or not) have two or more orthogonal components. Even if phase difference were to be a vector difference, this would not remedy Shapira's failure to disclose either component signals divided from relatively phase shifted first and second signals or a signal combining network for combining such component signals.

The Examiner's reference to paragraph [0017] of Shapira for supplying this teaching is not understood as it is irrelevant to the claimed invention. The cited paragraph merely refers to conventional phased array electrical tilting by means of phase shifting. The cited paragraph <u>does not</u> disclose or suggest splitting relatively phase shifted signals into components and combining the components to provide antenna element drive signals. Conventional phased array electrical tilting requires (N-1) variable phase shifters for an array having N antenna elements. For each of Shapira's two arrays, N = 2 so (N-1) = 1 variable phase shifter per array implemented as phase shifters 26 and 28.

Moreover, Shapira's paragraph [0096] makes it clear that electrical tilt or squint is an optional feature which requires additional phase shifters (RET is a term of art meaning remote electrical tilt [control]). There is however no detailed disclosure in Shapira of how electrical tilt is achieved. The most that is disclosed is in paragraph [0098] describing Fig. 13, which indicates squint control is achieved in some unspecified way using phase shifters in dual beamers 1302.

It is instructive to compare Shapira's Figure 3 with Figure 3 of Applicant's specification: Shapira's Figure 3 shows splitters (not referenced) immediately above boxes labeled "Duplex"

and equivalent to Applicant's splitter 44 which splits an input signal into first and second signals. Shapira's Figure 3 also shows variable phase shifters 26 and 28, each of which introduces a relative phase shift between a respective pair of first and second signals and thereby corresponding to Applicant's variable phase shifter 46. However, Shapira's Figure 3 does not show any equivalent of the following items in Applicant's Figure 3: i.e. first and second signal splitters 52 and 54 which produce component signals from relatively phase shifted first and second signals, or vector combining network 60 which combines component signals (shown in more detail in Figure 4).

The Examiner acknowledges that "Shapira does not disclose a vectorial combiner for combining first or second signals for providing drive signals for each individual antenna element." However, the Applicant does not understand the relevance of this remark, because Applicant's invention does not use a vectorial combiner for combining first or second signals to provide antenna element drive signals. Instead Applicant's invention requires a vectorial combiner for combining components into which first and second signals have been divided. Therefore, if the Examiner's rejection relied upon Thomas 72 for supplying this allegedly missing teaching of Shapira, then the Examiner's rejection must be withdrawn because the rejection is not directed to the Applicant's claimed invention.

In what follows, Applicant will assume that the Examiner intended to state that "Shapira does not disclose a vectorial combiner for combining components into which first and second signals are divided for providing drive signals for each individual antenna element." The Examiner goes on to state that "Thomas 72 teaches the use of second splitter and a combining network (article 124 in FIG. 6 below) for producing component signal *(sic)* as drive signal *(sic)* for each individual element for controlling antenna tilt (paragraph 0004-0005)" (Applicant's italics). However, Applicant's invention does not use component signals to provide antenna element drive signals. Instead Applicant's invention uses vectorial combinations of component signals to provide antenna element drive signals. For this reason as well, the Examiner's obviousness rejection of claims 1, 5, 11, 13, 16, 20, 26 & 28 must be withdrawn.

The Examiner also states that "It would have been obvious to modify Shapira with Thomas 72 by incorporating the claimed feature in order to extract out the drive signal *(sic)* with various combination *(sic)* of phase and amplitude and use it *(sic)* for controlling antenna electric

tilt". Applicant presumes this should read "... drive signals with various combinations of phase and amplitude and use them...". The Examiner's basis for combining the references is faulty for at least three different reasons. In brief:

a) It is not possible to modify Shapira with Thomas 72 without conflicting with the purpose and objectives of Shapira, and Shapira and Thomas are not properly combined;

b) The signals which are combined by Thomas 72 are not vectorial combinations of component signals (i.e. fractions) divided from first and second signals; and

c) Thomas 72 does not disclose antenna element drive signals varying in phase progressively across the array with antenna element position, unlike Applicant's amended claims 1 and 13.

Regarding item a), Shapira and Thomas 72 are not being properly combined by the Examiner. Applicant submits it is impossible to combine Shapira with Thomas because they have totally different objectives and implementations. Shapira (see e.g. Figure 3) relates to a pair of phased arrays, each array consisting of the minimum number of antenna elements required for a phased array, i.e. two elements 22 in one array and two elements 24 in the other array. Beams from the two phased arrays have different polarisations, $+45^{O}$ and -45^{O}, and they are steerable towards or away from one another to form a narrow dual polarised beam or a wide beam respectively (paragraphs [0062] and [0063]). Shapira is not concerned with electrical tilt of a single beam except as an optional extra (paragraph 0096). Since Shapira only uses two antennas for each phased array, there is absolutely no reason for Shapira to split antenna signals into more than two fractions or components because there are no antenna elements to receive the additional signals so formed: the additional signals would therefore be unwanted, and they would deleteriously affect operation of Shapira's antenna system by interfering with required signals. Consequently, absent the hindsight provided by reading Applicant's patent specification, one of ordinary skill in the art reading Shapira would obtain no motivation whatsoever for splitting antenna signals into more than two fractions as per Thomas 72, because to do so would be completely purposeless and would result in worse performance of Shapira's system.

As regards b) above, the signals which are combined by Thomas 72 are not vectorial combinations of component signals (i.e. fractions) divided from first and second signals. Instead

each vectorial combination is obtained from a fraction of a signal X or Y say supplied to one of the upper and lower groups combined with a signal $Y_\perp$ or $X_\perp$ say in quadrature with (90° phase shift relative to) a signal Y or X supplied to the other of the upper and lower groups. This is because quadrature hybrid couplers 174A and 174B are used by Thomas 72 for signal combining as shown in more detail in Figure 7 (Thomas 72 does not disclose any other method of combining signals). A quadrature hybrid coupler shifts the phase of one of its output signals by 90^{O} relative to the other of its output signals. Consequently, at quadrature hybrid outputs connected to respective antenna elements, there will be an antenna element drive signal which is the sum of in phase and quadrature signals; i.e. at these outputs there will be an antenna element drive signal $X + Y_\perp$, and at the other output $X_\perp + Y$: this is quite different to Applicant's invention, which produces antenna element drive signals of the kind $fA \pm gB$, $fA \pm gB \pm hB$, and $fA \pm gA \pm hB$, where f, g and h are zero or fractions less than 1, i.e. $0 \leq f$, g and $h < 1$. In this regard please see e.g. Table 3 on page 27 of Applicant's specification.

As regards c) above, Thomas 72 does not disclose antenna element drive signals varying in phase progressively across the array as a function of antenna element position. Instead Thomas 72 discloses a stepwise variation in phase: the upper group of four antenna elements E1 to E4 all receive the same signal phase, the lower group of four antenna elements E9 to E12 all receive the same signal phase but shifted relative to that of the upper group; the central group of four antenna elements E5 to E8 receive signals with phases intended to be the average of those of the other groups but these elements' drive signals are subject to amplitude spoiling and phase spoiling.

Amplitude spoiling arises because signals on central elements E5 to E8 have amplitudes which vary with change in the phase shift ϕ between upper and lower group signals: for example, signals on elements E6 and E7 have zero amplitude when ϕ is -90^{O} and signals on elements E5 and E8 have zero amplitude when ϕ is $+90^{O}$. This is a consequence of using quadrature hybrid couplers to produce antenna element drive signals for the central elements E5 to E8.

Phase spoiling arises from two different causes, the first cause being as follows. In Figure 7 of Thomas 72, there are -45 degree phase shifts at 170A and 170B: consequently, for $-90 < \phi < 90$, the drive signal phases of the central sub-group of elements E5 to E8 are all the same and equal to $-\frac{1}{2}\phi$ relative to those of all of the upper sub-group of elements E1 to E4

(outside the interval $-90 < \phi < 90$ this no longer applies). The drive signal phases of the lower sub-group of elements E9 to E12 are also all the same and equal to $-\phi$ relative to those of all of the upper sub-group of elements E1 to E4. This means there is a total of only three phase values for the whole twelve element array, not twelve different phases which is required for ideal phased array operation: consequently, phase does not vary progressively across the array, unlike Applicant's invention as claimed in claims 1 and 16 . Instead in Thomas 72 phase varies very coarsely stepwise in three steps or one step per sub-group of four elements: consequently only two pairs of adjacent elements E4/E5 and E8/E9 have phase differences between their two drive signals, nine pairs E1/E2, E2/E3, E3/E4, E5/E6, E6/E7, E7/E8, E9/E10, E10/E11 and E11/E12 do not have any such phase difference. Thomas 72 therefore does not disclose antenna element drive signal phase varying progressively across the array as a function of antenna element position, which results in a first contribution to phase spoiling for Thomas 72.

A second contribution to phase spoiling for Thomas 72 arises because the amplitudes of the two outputs from each quadrature hybrid coupler in Figure 7 contain cosine terms which differ; i.e. one of these cosine terms includes $+\frac{1}{2}\phi$ and the other includes $-\frac{1}{2}\phi$. A change in amplitude from positive to negative is equivalent to a phase change of π: Consequently, when ϕ changes sufficiently to change amplitude from positive to negative, the phase of associated antenna element drive signals effectively changes abruptly by π, which completely ruins the phase distribution of antenna element drive signals.

A detailed derivation of the amplitude spoiling and phase spoiling effects discussed above is set out in the Appendix A of this Reply, together with a schematic drawing of a quadrature hybrid coupler and drawings illustrating phase spoiling. The Examiner's combination of Shapira with Thomas is faulty for each of the reasons a), b) and c) above and for each of the reasons, the Examiner's rejection of claims 1, 5, 11, 13, 16, 20, 26 & 28 for obviousness must be withdrawn on these grounds as well.

B. Claims 5, 11, 20 And 26 Are Non-Obvious

Turning now to claims 5, 11, 20 and 26, the Examiner states that Shapira discloses a splitting apparatus (article 38) divides *(sic)* component signal *(sic)* for input to the signal phase shifting *(sic)* (article 26, 28) and combining network (article 20) (see FIG. 3 above). The syntax here is rather obscure, but Applicant will assume that what is intended is: "Shapira discloses a

splitting apparatus (article 38) which divides a component signal for input to the signal phase shifting apparatus (article 26, 28) and combining network (article 20) in Shapira's Fig. 3."

In this connection, it is respectfully submitted that the Examiner has not understood Shapira or Applicant's invention, because:

d) splitting apparatus 38 does not divide a component signal as defined in Applicant's claims 1 and 16 (a component signal is produced by splitting one of two relatively phase shifted signals and multiple component signals are used to produce antenna element drive signals): instead splitting apparatus 38 divides a signal into two signals one of which is fed to one phased array and the other is fed to a different phased array; i.e. two completely separate phased arrays are involved, not one array, and they are referred to as main and diversity branches in paragraph [0060];

e) in Applicant's invention as claimed in claims 1 and 16, component signals are not input to signal phase shifting apparatus but are output from splitters one of which splits the output from a variable phase shifter; and

f) Shapira's article 20 is not a combining network: instead it is a dual polarised antenna column - see paragraph [0056]. If Shapira's article 20 were to be a combining network, Shapira's disclosure would be totally unable to function as described: this is because it would mean that the signals intended for antenna elements of different polarisations would be combined: i.e. signals intended for antenna elements 22 and 24 in right hand box 20 after phase shifting at 26, 28 respectively would be combined and signals intended for antenna elements 22 and 24 in left hand box 20 without such phase shifting would be combined. In consequence, Shapira's two phased arrays could not be steered towards or away from one another contrary to paragraphs [0062] and [0063].

The Examiner states that "all devices are co-located on the same platform since they are antenna on the same sector of a same base station", and mentions claims 10 and 26. Here again the Examiner appears to be working from the wrong set of claims because claim 10 was cancelled in the response to the previous action. Moreover, claim 26 relates to feeding the primary signal as a single input signal from a remote source, for splitting, variable phase shifting

and forming vectorial combinations in a network co-located with the antenna array to and forming therewith an antenna assembly. Shapira does not disclose feeding an input signal from a remote source or forming vectorial combinations and therefore cannot anticipate claim 26, and does not in fact state where the base station is located relative to the antennas 20.

Regarding claims 13 and 28, the Examiner acknowledges that Shapira fails to specifically disclose use of a first variable phase shifter connected in a transmit mode, and a second variable phase shifter connected in receive mode. Here Applicant will assume that "channel" should be substituted for "mode" to reflect the contents of claims 13 and 28.

The Examiner goes on to state that "Thomas 72 teaches two variable phase shifter *(sic)* with first splitter". The Examiner acknowledges that Thomas 72 does not specifically disclose that one variable phase shifter is for transmit and the other one is for receive. In fact both of Thomas 72's variable phase shifters 132 and 134 in Figure 6 are used in transmit mode and both variable phase shifters 132 and 134 are also used in receive mode. This is because there is a single phase difference between signals output from variable phase shifters 132 and 134 upwards in the drawing in transmit mode and downwards in receive mode, and this single phase difference controls the transmit or receive beam direction of the array of antenna elements E1 to E12. Consequently, the Thomas 72 disclosure provides an array beam direction which is necessarily the same for both transmit mode and receive mode. Thomas 72 therefore does not disclose first and second variable phase shifters in different channels, i.e. transmit and receive channels, and cannot provide independently adjustable electrical tilt in transmit and receive modes, unlike Applicant's invention as claimed in claims 13 and 28.

The Examiner further states that it is a common implementation in cellular cell *(sic)* by using one fee (sic, feed?) cable for TX antenna and another receive cable for RX antenna. The Examiner's statement is irrelevant as claims 13 and 28 do not relate to two separate TX and RX antennas with separate feed cables. Instead, claims 13 and 28 relate to one antenna and the same feed cable (Figure 11) or cables (Figure 12) being used for both transmit and receive with independent tilt control in both cases. In this regard please see the embodiment of Applicant's invention described on page 35 line 3 to page 36 line 9 where it is shown in Figure 13, and operates in TX and RX modes with only one antenna array 262.

C. Claims 14-15 And 29-30 Are Non-Obvious

Claims 14-15 and 29-30 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shapira in view of Thomas 72, as applied to claims 1 and 16, and further in view of Thomas 55. This rejection is traversed for the same reasons as those given in Section II(A) above in connection with claims 1 and 16 from which claims 14-15 and 29-30 depend respectively, directly or indirectly.

Regarding the specific objections to claims 14-15, 29-30, the Examiner states that "Shapira discloses use of two variable phase shifters and combiner". The Examiner is wrong in this regard. As previously discussed in detail, Shapira's article 20 is not a combining network. Instead article 20 is a dual polarised antenna column - see paragraph [0056]. If Shapira's article 20 were to be a combining network, Shapira's disclosure would be totally unable to function as described.

The Examiner acknowledges that Shapira ("in view of in view of Thomas 72") fails to disclose a plurality of variable phase shifters associated with respective operators and filtering (claim 14), respective pair of variable phase shifters for each operator (claims 15, 29), components have both forward and reverse signal processing (claim 30). The Examiner states that Thomas 55 teaches the use of filtering (paragraph 0009) and variable phase shifter associated with respective operator (two for each operator) (paragraph 0170) (FIG. 14) and tilt control unit 704 (article 704 in FIG. 12).

However, paragraph 0170 relates to Figure 11, not Figure 14, and neither Figure 11 nor Figure 14 uses filters for the reason given in Thomas 55's paragraph 0009 – i.e. because filters do not work acceptably when operator frequencies are close together ("contiguous"). Consequently, contrary to the Examiner's remarks, Thomas 55 teaches away from the use of filtering and claims 14-15 and 29-30 are independently non-obvious for at least this reason.

The Examiner goes on to state that and that it would have been obvious to further modify Shapira ("in view of in view of Thomas 72") with Thomas 55 by incorporating filtering and corresponding variable phase shifter, tilt control processing for respective operator in order to extract the wanted signal frequency and be capable of individually control [sic] each operator's tilt requirement in transmit or receive mode. If this objection is maintained Applicant would be

grateful for the Examiner supplying more complete details of how it might be done, because it appears to be impossible.

Applicant believes it to be impossible to combine Shapira ("in view of in view of Thomas 72") with Thomas 55 because Shapira and Thomas 55 have totally different objectives and implementations. Shapira (see e.g. Abstract) relates to a pair of phased arrays, with each array having two antenna elements only; the phased arrays have respective beams with different polarisation, and the beams are steerable together to form a narrow dual polarisation beam or steerable apart to form a wide beam. Shapira is not concerned with electrical tilt except as an optional extra (paragraph 0096). Thomas 55 relates to signal combining for sharing of a phased array (e.g. twelve antenna elements Figure 8a) by multiple operators such as five, with different operating frequencies and independently adjustable angles of electrical tilt. Shapira discloses a single beam with a single frequency for each phased array. Shapira therefore has no use whatsoever for signal combining, filters, multiple operating frequencies or independently adjustable angles of electrical tilt. Applicant respectfully submits that Shapira and Thomas 55 are not properly combined and claims 14-15 and 29-30 are non-obvious for this reason as well.

Regarding claims 15 and 30, Shapira fails to disclose respective pairs of variable phase shifters for multiple operators because Shapira has only one operator for two phased arrays because there is only one input (transmit) signal at 36 corresponding to only one operator. Shapira therefore cannot usefully employ pairs of variable phase shifters for multiple operators and claims 15 and 30 are non-obvious and patentable for this reason as well.

D. Claims 2, 6-7, 17 And 21-22 Are Non-Obvious

Claims 2, 6, 7,17, 21 and 22 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shapira in view of Thomas 72, as applied to claims 1 and 16, and further in view of Gordon (5410321). This rejection is traversed for the same reasons as those given above in Section II(A) in connection with claim 1 and 16 from which claims 2, 6 and 7 depend and claim 16 from which claims 17, 21 and 22 depend, directly or indirectly in each case.

Regarding the specific objections to claims 2, 6, 7, 17, 21 and 22, the Examiner acknowledges that Shapira fails to disclose use of [an] odd number of antenna elements (claims 2, 17), hybrid couplers (claims 6, 21) or 180 degree hybrid couplers (claims 7, 22). However, the Examiner goes on the state that Gordon teaches the use of [an] odd number [of] antenna elements

and 180 degree hybrid couplers for combining signal[s], and that it would have been obvious to modify Shapira with Gordon by incorporating [a] 180 degree hybrid coupler and [an] odd number [of] elements in order to reduce interference between antenna elements.

Shapira and Gordon are not properly combined, because it is an essential element of Shapira that it employs two phased arrays with each array having two antenna elements only, not an odd number of antenna elements. (See Shapira at e.g. the Abstract line 7, Invention Summary, paragraph [0010] line 8, paragraph [0047] lines 14 to 18, paragraph [0056] lines 8-9, paragraph [0061] line 5, paragraph [0062], and claim 1 lines 7 to 9). Inserting an odd number of antenna elements into Shapira, therefore would make Shapira unworkable and claims 2, 6, 7, 17, 21 and 22 are non-obvious for at least this reason.

The Examiner justifies modifying Shapira with Gordon on the basis that it will reduce interference between antenna elements. However, Shapira does not have a problem with interference between antenna elements because Shapira employs two phased arrays both carrying the same signal produced by splitting a single input signal to splitter 36 in Figure 6. There are therefore no different signals to interfere with one another. Moreover, adding antenna elements and hybrid couplers does not necessarily provide any beneficial effect whatsoever regarding interference between antenna elements. It could in fact easily worsen interference between antenna elements because it might reduce spacing between circuit components. Claims 2, 6, 7, 17, 21 and 22 are therefore, non-obvious because the Examiner's motivation for combining the references is faulty.

E. Claims 3-4 And 18-19 Are Non-Obvious

Claims 3-4, 18-19 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shapira in view of Thomas 72, as applied to claim 1 (presumably also claim 16) above, and further in view of Kuramoto, US Pat. No. 5281974. This rejection is traversed for the same reasons as those given above at Section II(A) in connection with claim 1 and 16 from which claims 3 and 4 depend and claim 16 from which claims 18 and 19 depend.

The Examiner takes the position that Shapira, as modified with Thomas 72, discloses a phased array antenna but fails specifically to disclose use of serial connection of first and second variable phase shifters (claim 3, 18) or a plurality of phase shifters such that some of the signals passed through all second variable phase shifters and some have not (claims 4, 19). In passing,

here again the Examiner appears to be referring to the claims as on file prior to the response to the previous action: *inter alia*, "passed through" was deleted from claims 4 and 19 in that response.

The Examiner goes on to state that Kuramoto discloses use of first and second variable phase shifters and a plurality of variable phase shifters in Figure 2. He also states that it would have been obvious to modify Shapira ("in view of in view of Thomas 72") with Kuramoto in order to do impedance matching or reducing intermodulation noise. This is traversed on three separate counts as follows:

g) Firstly, adding further phase shifters to Shapira has no effect whatsoever on impedance matching or reducing intermodulation noise – in fact it could easily worsen both: consequently so this justification for combining Shapira ("in view of in view of Thomas 72") with Kuramoto fails;

h) Secondly, Kuramoto's Figure 2 shows all signals going through the same number of variable phase shifters: all signals go through the third variable phase shifter 28, then either through the first variable phase shifter 21 or through the second variable phase shifter 22. This is not as claimed in claims 4 and 19, which require some signals to passed through all second variable phase shifters and some have not; and component signals some of which have a phase shift applied collectively by all the variable phase shifters, and some of which have not; and

i) Thirdly, it is an essential element of Shapira that it employs phased arrays each having two antenna elements and two antenna element drive signals only, and each phased array requires only one phase shift between its signals. Shapira therefore does not need additional variable phase shifters, so motivation for one of ordinary skill to search for Kuramoto to add further phase shifters from is absent.

Thus claims 3-4 and 18-19 are independently non-patentable for each of the reasons recited above.

F. Claims 8-9, 23 And 31-33 Are Non-Obvious

Claims 8-9, 23, and 31-33 are rejected under 35 U.S.C. 103(a) as being unpatentable over Shapira in view of Thomas 72, further in view of Gordon (5410321), as applied to claims 1, 6, 16, 21 above, and yet further in view of Boire (4749969). This rejection is traversed for the same

reasons as those given in Section II(A) above in connection with claims 1 and 16 from which all of the rejected claims depend. Additionally, claims 3-4 and 18-19 are non-obvious and patentable for the same reasons raised in connection with claims 2, 6, 7, 17, 21 and 22 in Section II(D) above because Shapira and Gordon are not properly combined, because inserting Gordon's odd number of elements into Shapira would make Shapira unworkable.

The Examiner takes the position in this rejection that Shapira ("in view of Thomas 72") as further modified by Gordon fails to disclose ring hybrids with circumference $(n+1/2)\lambda$, neighbouring ports separated by $\lambda/4$ (claims 8, 23,33), and an input terminal with resistor for impedance matching (claims 9, 33). However, the Examiner states that Boire teaches a 180 degree hybrid ring phase shifting apparatus with 1.5 (1+ 1/2) wavelength circumference and 1/4 wavelength spacing ("rat rate" column 1, lines 14-37) and resistor for impedance matching (column 3, lines 28-38). The Examiner goes on to state that it would have been obvious to further modify Shapira with Boire by incorporating as claimed circumference, spacing and resistor in order to satisfy hybrid design specifications and requirement of element spacing in an antenna array.

However, at column 1 lines 11-12, Boire states that the invention is suitable for interface with hybrid micro-electronic structures. Absent the hindsight provided by knowledge of Applicant's invention, there is no reason to look at micro-electronics to find circuit elements for circuit boards suitable for much higher power RF applications such as phased arrays. Therefore, the Examiner's combination of the cited references with Boire is without support and claims 8-9, 23, and 31-33 must be allowed.

Claims 8-9, 23, 33 are directed to the embodiment described in Applicant's specification at page 39 line 5 to page 43 line 8 with reference to Figure 16. As Figure 16 shows, it is a very compact arrangement: moreover, most of the components are ring hybrids, which reduces problems arising from dissimilar components having different variations in properties as signal frequency changes.

Moreover, claims 8-9, 23, and 31-33 are patentable because the claimed invention does not follow from the combination of the references. The Examiner acknowledges that Shapira ("in view of Thomas 72 and Gordon") as further modified by Boire fails to disclose hybrids designed to convert input signal I1 and I2 into vector sum or difference. Because a hybrid can be

and is in Applicant's Figure 16 used as a splitter, absent the hindsight provided by knowledge of Applicant's invention, it is not automatic that Boire provides vector sum or difference.

CONCLUSION

Claims 1-9, 11-23 and 26-33 are pending in this application and are believed to be patentable for the reasons recited above. Favorable reconsideration and allowance of the pending application claims is, therefore, courteously solicited.

Respectfully submitted,

Date: September 2, 2008

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APPENDIX A

1. Page and line numbers of Applicant's specification cited below refer to the International patent specification as published.

2. Thomas 72 fails to remedy the deficiencies of Shapira for the following reasons:

    a) Thomas 72 does not disclose forming vectorial combinations of first and second component signals to provide antenna element drive signals;

    b) Thomas 72's antenna element drive signals do not vary in phase progressively across the array as a function of antenna element position– instead they produce phase spoiling. In addition Thomas 72's antenna element drive signals have amplitude spoiling; and

    c) the angle of electrical tilt of Thomas 72's array is not correctly adjustable in response to alteration of the variable relative phase shift.

3. Regarding vectorial combinations of first and second component signals, Thomas 72 discloses a first signal (vector **A** say) fed to all four antenna elements E1 to E4 in an upper sub-group, and a second signal (vector **B** say) fed to all of another four antenna elements E9 to E12 in a lower sub-group. Vectors **A** and **B** are derived by splitting a signal into two signals and inserting a relative phase shift between the split signals; consequently **A** and **B** differ in phase but are otherwise equivalent. A proportion of each of **A** and **B** is also fed to respective inputs of two quadrature hybrids or combiners 174A and 174B in Figure 7 described at page 22 line 6 to page 23 line 21: the expression "quadrature" means that each of these hybrids inserts a -90 degree relative phase shift between signals passing from each input to a respective output. It combines signals with and without this phase shift respectively, and feeds the combination to a central sub-group of antenna elements E5 to E8.

4. The signals which are combined in Thomas 72 by quadrature hybrids 174A and 174B are not combinations of fractions of first and second signals **A** and **B**: one of the output signals from each hybrid is instead a combination of a fraction of **A** with a fraction of a vector, $\mathbf{B}_{\perp}$ say, in quadrature with **B**, because of the hybrid's insertion of a –90 relative phase shift; similarly, the other output signal from each hybrid is a combination of a fraction of **B** with a fraction of a vector, $\mathbf{A}_{\perp}$ say, in quadrature with **A**. Thomas 72 does not disclose any other method of combining signals. Thomas 72 therefore does not disclose signal combinations as claimed in Applicant's claim 1d).

5. Moreover, the difference between the signal combining arrangements of Thomas 72 and Applicant's invention is very important because it leads to an important technical advantage – improvement with regard to amplitude and phase spoiling: in this connection, analysis of the operation of the hybrids 174A and 174B shows that drive signals on the central sub-group of elements E5 to E8 have amplitudes which vary as the relative phase difference between signals **A** and **B** varies on the upper and lower sub-groups respectively. Furthermore, the signals on the antenna elements E5 to E8 are subject to phase spoiling, i.e. they do not vary correctly with change in the relative phase

difference between fractions of signals **A** and **B**.

6. To demonstrate this deficiency of Thomas 72, assume for convenience that the signals input to the quadrature hybrids 174A and 174B in Figure 7 are A and B of equal amplitude K (similar remarks apply if they are not) and there is a variable phase shift ϕ between A and B; then:

$$A = K\sin\omega t$$

$$B = K\sin(\omega t - \phi)$$

7. With the -90 phase shift of between each input and a respective one of the outputs, each of the Thomas 72 hybrids 174A and 174B produces $A + B_\perp$ at output C and $A_\perp + B$ at output D; here $A_\perp$ and $B_\perp$ are vectors of equal amplitude with but perpendicular to or in quadrature with A and B respectively, i.e. $A_\perp = K\sin(\omega t - 90)$ and $B_\perp = K\sin(\omega t - \phi - 90)$. The signals at outputs C and D are then given by:

$$A + B_\perp = K\sin\omega t + K\sin(\omega t - \phi - 90) = 2K\sin\tfrac{1}{2}(2\omega t - \phi - 90)\cos\tfrac{1}{2}(\phi + 90)$$

$$= 2K\sin(\omega t - \tfrac{1}{2}\phi - 45)\cos\tfrac{1}{2}(\phi + 90), \text{ and}$$

$$A_\perp + B = K\sin(\omega t - 90) + K\sin(\omega t - \phi) = 2K\sin\tfrac{1}{2}(2\omega t - \phi - 90)\cos\tfrac{1}{2}(\phi - 90)$$

$$= 2K\sin(\omega t - \tfrac{1}{2}\phi - 45)\cos\tfrac{1}{2}(\phi - 90)$$

8. Consequently, for each of the antenna elements E5 to E8, the amplitude of the antenna drive signal varies cosinusoidally with ϕ as the variable phase shift ϕ changes; for example, when $\phi = 90$, $\cos\tfrac{1}{2}(\phi + 90)$ is zero but $\cos\tfrac{1}{2}(\phi - 90)$ is 1, and vice versa when $\phi = -90$, i.e. $\cos\tfrac{1}{2}(\phi + 90)$ is 1 but $\cos\tfrac{1}{2}(\phi - 90)$ is zero. This variation in amplitude is referred to as amplitude spoiling. For all the other eight antenna elements E1 to E4 and E9 to E12, the amplitudes of the drive signals are constant when ϕ changes.

9. Turning now to the variation of Thomas 72's drive signal phase with antenna element position in the array, by virtue of -45 degree phase shifts at 170A and 170B, for $-90 < \phi < 90$, the drive signal phases of the central sub-group of elements E5 to E8 are all the same and equal to $-\tfrac{1}{2}\phi$ relative to those of all of the upper sub-group of elements E1 to E4 (outside the interval $-90 < \phi < 90$ this no longer applies as described later). The drive signal phases of the lower sub-group of elements E9 to E12 are also all the same and equal to $-\phi$ relative to those of all of the upper sub-group of elements E1 to E4. This means there is a total of only three phase values for the whole twelve element array, not twelve different phases which is required for ideal phased array operation: consequently, phase does not vary substantially linearly across the array with phase changes between all adjacent elements. Instead in Thomas 72 phase varies very coarsely stepwise in three

steps or one step per sub-group of four elements: consequently only two pairs of adjacent elements E4/E5 and E8/E9 have phase differences between their two drive signals, nine pairs E1/E2, E2/E3, E3/E4, E5/E6, E6/E7, E7/E8, E9/E10, E10/E11 and E11/E12 do not have any such phase difference. Thomas 72 therefore does not disclose antenna element drive signal phase varying progressively across the array as claimed in Applicant's claims 1 and 16; this results in a contribution to phase spoiling for Thomas 72 (a second such contribution also arises as will be described later).

10. Unlike Thomas 72, embodiments of Applicant's invention described in the patent specification have capability for providing all antenna elements in a phased array with individual drive signals varying in phase in accordance with a substantially linear function of antenna element position in the array – i.e. with phase change between antenna elements in each adjacent pair: this enables Applicant's invention to achieve normal phased array operation without significant phase spoiling other than when an optional minor phase taper is implemented, as is often required (as described later). In this connection please see e.g. Table 3 on page 28 providing individual phases for drive signals for all twelve antenna elements; equivalents for ten antenna elements appear in Table 2 on page 21 and Table 5 on page 32.

11. Furthermore, the angle of electrical tilt of embodiments of Applicant's invention is adjustable by means of the variable phase shifter, i.e. by changing a single phase difference: this is because in response to operation of the variable phase shifter, in these embodiments all antenna element drive signals change appropriately in phase; relative to a reference phase on one array end element, all other element drive signal phases increase or decrease by different amounts. This technical result is not achieved by Thomas 72.

12. Regarding adjustment of the angle of electrical tilt of Thomas 72's array, here again this is affected by the drive signals for each of the sub-groups of elements (E1 to E4, E5 to E8 and E9 to E12) being constant in phase for $-90 < \phi < 90$. Signals on individual central elements E5 to E8 also vary in amplitude sinusoidally: The drive signals for the phased array of elements E1 to E12 therefore produce amplitude and phase spoiling as has been said, and so the angle of electrical tilt of Thomas 72's array is not correctly adjustable in response to alteration of the phase shift between signals **A** and **B**. Thomas 72 therefore does not disclose the angle of electrical tilt of the array being correctly adjustable in response to alteration of the variable relative phase shift as claimed in Applicant's claim 1.

13. A second contribution to phase spoiling for Thomas 72 arises as follows. A physical view of each of the hybrids 174A and 174B in Figure 7 of Thomas 72 appears in Figure 1 of the first drawing sheet accompanying this ANNEX. Each of these hybrids is square in shape with inputs A and B and outputs C and D connected to one pair of adjacent central antenna elements E5/E6 or E7/E8 (not shown). At operating frequency, each side of the

square is ¼λ long or 90^{O} in terms of phase change: this phase change is relative between outputs, it being necessary to apply 180^{O} to get absolute phase.

14. Input A is isolated from input B, and a signal which is input at A is equally split between outputs C and D. A signal passing along one side of the square from input A to output D has 90^{O} phase change, but along two sides of the square from input A to output C a signal has 180^{O} phase change. Similarly a signal passing from input B to output C has 90^{O} phase change, but a signal passing from input B to output D has 180^{O} phase change.

15. Let V_A and V_B be signals input to A and B respectively, ω be signal angular frequency, and V_C and V_D be signals output at C and D respectively.

If $V_A = \sin(\omega t)$, and $V_B = 0$:

then $V_C = \frac{1}{\sqrt{2}}\sin(\omega t - 180) = \frac{-1}{\sqrt{2}}\sin(\omega t)$, and

$$V_D = \frac{1}{\sqrt{2}}\sin(\omega t - 90)$$

16. There is a phase difference ϕ between signal V_A applied to upper antenna elements E1 to E4 and signal V_B applied to lower antenna elements E9 to E12 (ϕ arises from delays equivalent to 132 and 134 in Figure 6). It is convenient to express ϕ as $-\frac{1}{2}\phi$ applied to V_A and $+\frac{1}{2}\phi$ applied to V_B, because this corresponds to zero phase intended by Thomas 72 for signals applied to central antenna elements E5 to E8.

i.e. $V_A = \sin\left(\omega t - \frac{\phi}{2}\right)$ and $V_B = \sin\left(\omega t + \frac{\phi}{2}\right)$

Consequently $V_C = \underbrace{\frac{1}{\sqrt{2}}\sin\left(\omega t + \frac{\phi}{2} - 90\right)}_{\uparrow\ \text{from } V_B} + \underbrace{\frac{1}{\sqrt{2}}\sin\left(\omega t + \frac{\phi}{2} - 180\right)}_{\uparrow\ \text{from } V_A}$

Applying the identity $\sin X + \sin Y \equiv 2\sin\frac{X+Y}{2}\cos\frac{X-Y}{2}$:-

$$V_C = \sqrt{2}\sin\left(\frac{2\omega t - 270}{2}\right)\cos\left(\frac{\phi + 90}{2}\right) = \sqrt{2}\sin(\omega t - 135)\cos\left(45 + \frac{\phi}{2}\right)$$

Similarly:

$$V_D = \sqrt{2}\sin\left(\frac{2\omega t - 270}{2}\right)\cos\left(\frac{90-\phi}{2}\right) = \sqrt{2}\sin(\omega t - 135)\cos\left(45 - \frac{\phi}{2}\right)$$

17. The above expressions for hybrid output signals V_C and V_D both have time varying terms $\sin(\omega t - 135)$ which are in phase with one another. They also have amplitudes $\sqrt{2}\cos(45 + ½\phi)$ and $\sqrt{2}\cos(45 - ½\phi)$ respectively, each of which varies in magnitude with ϕ and may be positive or negative depending on the value of ϕ: an amplitude becoming negative is equivalent to being multiplied by -1, and so it is equivalent to a phase change of 180^O. After applying 180^O to get absolute phase (as mentioned above), the phase value of $-135°$ in the time varying terms $\sin(\omega t - 135)$ of signals V_C and V_D is equivalent to the $-45°$ delay on signals applied to upper antenna elements E1 to E4 and signal V_B applied to lower antenna elements E9 to E12.

18. If signals V_C and V_D have amplitudes A_C and A_D, then:

$$A_C = \sqrt{2}\cos\left(45 + \frac{\phi}{2}\right)$$

$$A_D = \sqrt{2}\cos\left(45 - \frac{\phi}{2}\right)$$

If $-90 > \phi < 90$ then both A_C and A_D are positive.

19. At $\phi = 0$, amplitude is evenly distributed amongst the central antenna elements E5 to E8, each of which receives signal V_C or V_D; moreover, gain is maximised and the phase front is flat across all twelve antenna elements E1 to E12 – i.e. these elements all receive drive signals with the same phase.

20. When $\phi = -90$, $A_C = \sqrt{2}$, but A_D and V_D are both 0; i.e. power is applied to the outer pair E5 and E8 of the central antenna element group which receive V_C, but no power is applied to the inner pair E6 and E7 of this group which receive V_D; the gain is reduced and the phase front is +45 for the four upper antenna elements E1 to E4, 0 for central antenna elements E5 to E8 and -45 for the four lower antenna elements E9 to E12 as shown in Figure 2 of the attached second drawing sheet.

21. If $\phi = +90$ then the reverse of the $\phi = -90$ situation applies: i.e. the outer pair E5 and E8 of the central antenna element group receive zero power, but power is applied to the inner pair E6 and E7 of this group; the phase front is -45 for upper antenna elements E1 to E4, 0 for central antenna elements E5 to E8 and +45 lower antenna elements E9 to E12 as shown in the attached Figure 3.

22. However, performance worsens dramatically outside the $-90 > \phi < 90$ region. Putting $\phi >$ 90, +120 say, sends A_C negative but A_D remains positive: this change of sign is equivalent to phase shifting V_C by 180^O relative to V_D. Consequently, there is a discontinuous shift in the phase of signals passing to the outer pair of central antenna elements E5 and E8 which receive V_C relative to the phase of signals passing to the inner pair of central antenna elements E6 and E7 which receive V_D: this has a disastrous effect on both gain and side lobes. The attached Figure 4 shows the phase front for $\phi = +120$: it can be seen that the phase front for the outer pair of central antenna elements E5 and E8 is well outside the phase fronts at -60 and +60 for the upper and +lower antenna elements E1 to E4 and E9 to E12 respectively, despite the phase front being at zero for the inner pair of central antenna elements E6 and E7. This corresponds to a severe degree of phase spoiling. Similar effects occur at other values of ϕ outside the $-90 > \phi < 90$ region.

23. The Thomas 72 Figure 7 antenna is really only viable for ϕ between -90 and +90, which is very limiting. Moreover, there is phase spoiling even within this range, as gain decreases and side lobes increase because of the stepwise change in phase between upper, central and lower groups of elements but not within any of these groups. The gain is a maximum when the central group have the same signal amplitude - gain reduces when that is not the case.

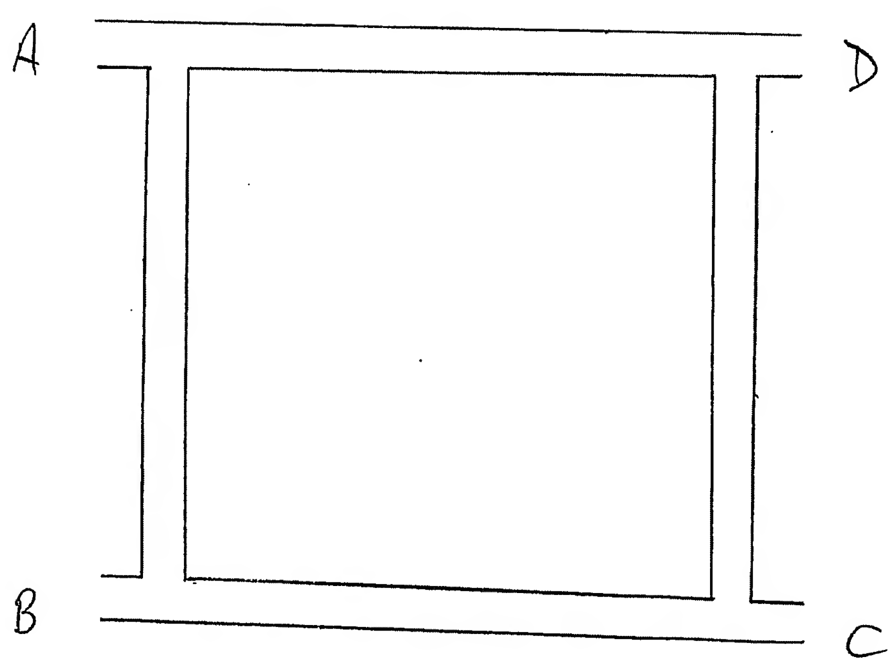


Fig. 1

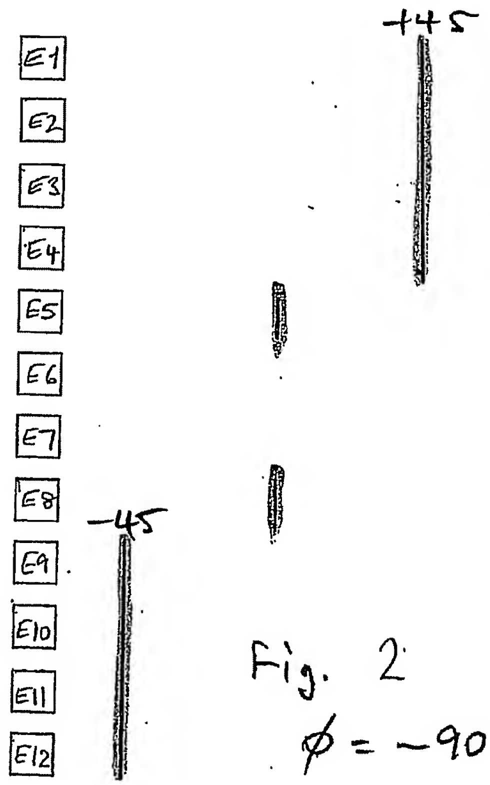


Fig. 2

$\phi = -90$

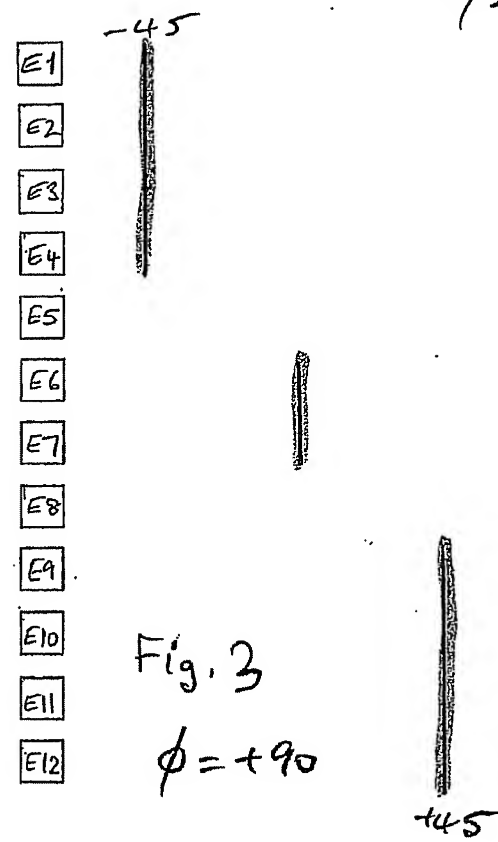


Fig. 3

$\phi = +90$

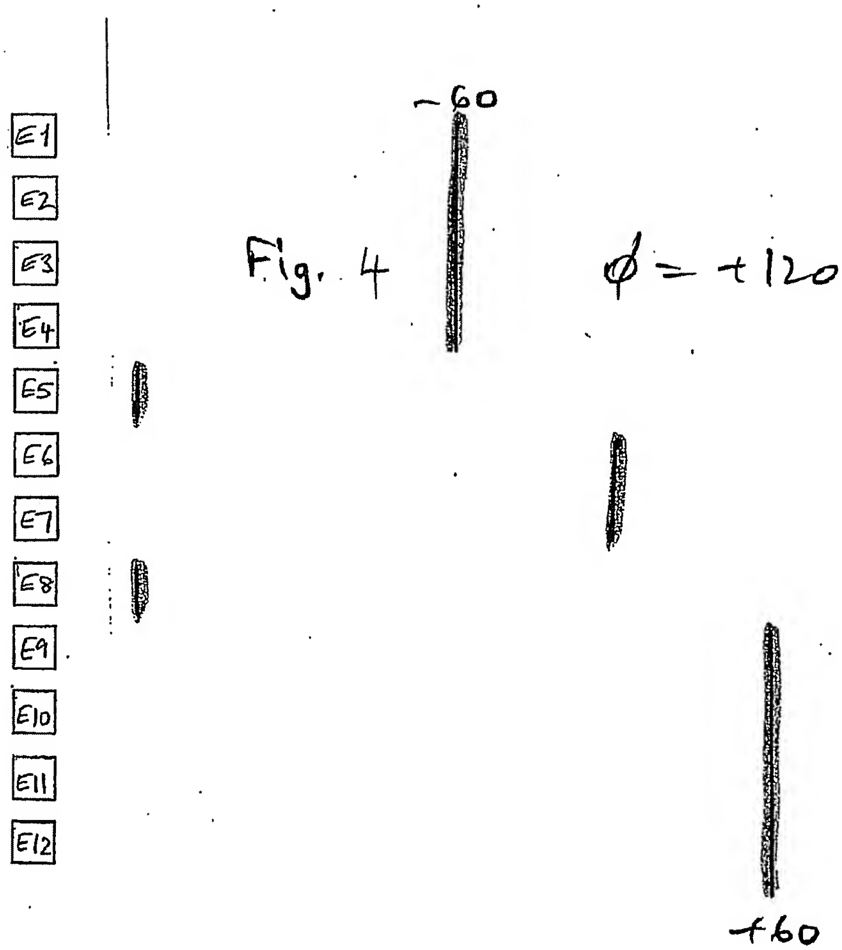


Fig. 4

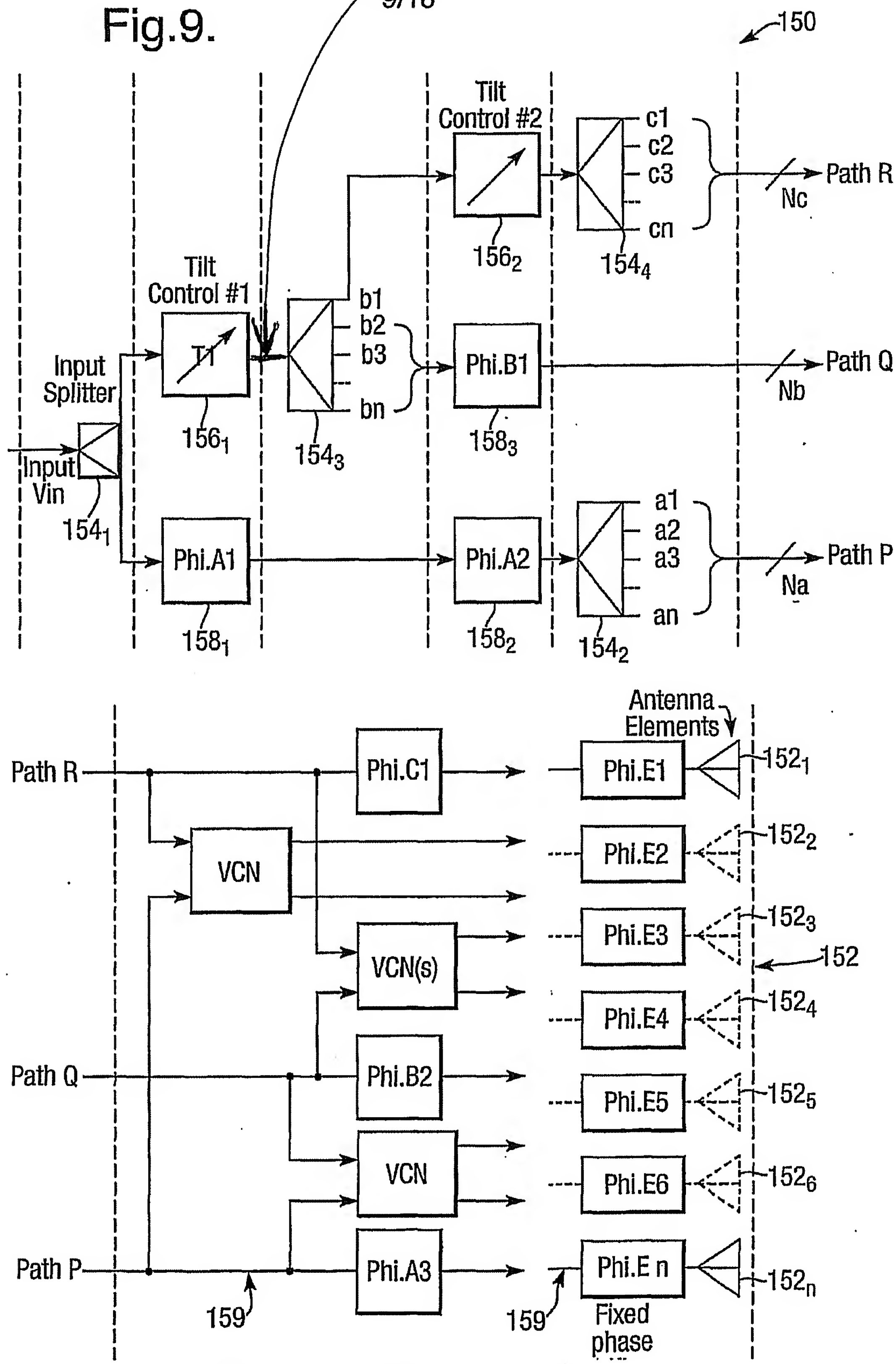
$\phi = +120$

Appendix B

(Marked Up Sheets – Figure 9)

link to be inserted

Fig.9.



Appendix C

(Replacement Sheets – Figure 9)